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Pain and Anxiety Treatment based on Social Robot Interaction with Children to improve Patient Experience. Ongoing Research*

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Abstract

A major focus for children's quality of life programs in hospitals is improving their experiences during procedures. In anticipation of treatment, children may become anxious and during procedures pain appears. The aim of this article is to introduce a proposal to design pioneering techniques based on the use of social robots to improve the patient experience by eliminating or minimizing pain and anxiety. According to this proposed challenge, this research aims to design and develop specific human-social robot interaction with pet robots. Robot interactive behavior will be designed based on modular skills using soft-computing paradigms.

1 Introduction

Children being diagnosed with a certain illness will experience unfamiliar and stressful procedures while in the hospital. In order to minimize the negative psychological impact of hospitalisation and treatment procedures, different programmes have been designed and implemented [Thompson and Stanford, 1981; Brewer *et al.*, 2006; Bagnasco *et al.*, 2012].

In this sense, the initial hypothesis for this research is that using pet robots endowed with *socially* situated behaviour able to develop the role of companion will help to cope with these stressful situations along all the hospitalization period and/or outpatient treatment [Nalin *et al.*, 2012]. Social skills are defined as the robot ability to adapt its behavior during the course of the interaction to remain a compelling companion and engage children over time even when novelty effect has worn off. In order to obtain user adaptation and socialization of the robot, machine learning and general soft computing paradigms will be designed and evaluated. Soft computing algorithms will be modularized in an easy form such that it can be implemented like simple building blocks in a specially designed programming environment. Moreover, children's anxiety and pain levels could be measured by observing how robots interacting with children have modified its behaviour.

Proposed experimental program is based on the *Child Life Program* [Thompson and Stanford, 1981], designed to help children and their families cope with the stresses of hospitalization. This program was started at Hospital Sant Joan de Déu (HSJD) in 2004 under management of Mrs. Núria Serrallonga [Serrallonga-Tintoré and Cabré-Segarra, 2010]. It is based on the idea that one of the best ways a child can learn to cope with their hospitalization is through regular play and medical play. This same idea is a basis of the recent research area in 'Serious Games' [Bergeron, 2006; Nilsson *et al.*, 2012; Oikonomou and Day, 2012] oriented mainly, but not uniquely, to elderly people. In 2010, more than 200 children and teenagers and their families have participated in this program in HSJD. This program is very usual in paediatric centres in the United States. Moreover, recent studies in 2012 include therapies like using iPads helping to reduce pain and anxiety in the children's ER (Emergency Room), using the technological novelty factor.

Methodological research will be completed by considering three different scenarios from three different points of views, building a 3x3 matrix of variable research difficulty. Scenarios will range from 'acute', even ER patients (traumatism, for instance), middle-term intervention (up to around 8 days) and long-term interaction, including long-term hospitalization and companionship at home (chronic diseases). The three-fold research vision includes the therapeutic related effect (including children's biological stress, analgesics delivery, perceived health state, mood, perception of social support, willingness to follow treatment), measured with clinical instruments, the quality of the children-pet robot interaction, measured with direct observation and subjective report techniques, and behavior modelling from the robot register, including temporal series evaluation using machine learning and data mining techniques [Breazeal, 2002; Looije *et al.*, 2010].

Hence, research's difficulty and novelty will vary from (i) the use of pet robots in short intercourses, where novelty effect is the most important factor for interactive behavior; (ii) validating anxiety and FLACC ('face, legs, activity, cry, consolability') pain scales when comparing clinical and psychological variables in middle-term interaction; (iii) to design effective behaviors for an engaging long-term interaction between children and pet robots; or (iv) to design new scales relating observed interaction and robot temporal series based on

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sensors and actuators. From the soft computing perspective, research will be performed (i) to design robot behaviors reducing pain and anxiety (machine learning), and (ii) to study relationships between clinical parameters, behavior and temporal series (data mining) in order to generate an evaluation method of pain and anxiety.

2 Aims of the Project

The overall aim is to design pioneering techniques based on the use of social robots to improve the children's experience when hospitalized by reducing pain and anxiety. Accordingly, this research aims to design and develop specific human social robot interaction with pet robots. Robot interactive behavior will be designed based on modular skills using soft-computing paradigms. In this form, project work can be divided in four main blocks according to the related scientific and technical areas:

1. Robot hardware, middle-ware and programming
2. Soft-computing paradigms for user adaptation, target behaviours, and knowledge extraction
3. Children-robot interaction, companionship and education capabilities
4. Children well-being and health

Here we describe the main aims for each block, expected outcomes and their relationships. Considered scenarios, experimentation and general work methodology will be detailed in the next section.

2.1 Robot Hardware, Middle-ware and Programming

The Pleo robot will be used as robotic platform because its shape, design, price, robustness and previous results shown in the scientific literature as well as European projects [Pitsch and Koch, 2010; Fernaeus *et al.*, 2010]. Moreover, from the point of view of interaction, it was strongly recommended by Ronald C. Arkin in private conversation during the R:SS2010 Conference. Required robot hardware modifications for the project are minimal; however they will be explored in the form of using different processing units and communication devices. Hence, several Pleo hacking implementations are expected like outcome, similar to those obtained from the FP7 LIREC project.

In reference with middle-ware, ROS (Robotic Operating System) by Willow Garage [Quigley *et al.*, 2009] will be evaluated as a possible implementation on Pleo. In this form, when the outcome is possible, many standard robot software modules will be directly available for the Pleo robot, following the Robotic Web 2.0 spirit.

Finally, in order to work on robot programming, a new programming environment is being developed (initially for the LS-Maker robot) in the form of graphical blocks, similarly to the Aldebaran Nao Robot Choreograph, National Instruments LabView or Lego MindStorms.

2.2 Soft-computing Paradigms

In order to obtain user adaptation of the robot, machine learning and general soft-computing paradigms will be designed and evaluated. Two different computing capacities will be considered: (1) mainly, it will be supposed that the robot is autonomous, so only the Pleo processor is available for programming; (2) as a second possibility, the Pleo robot will be communicated with an external PC.

The first case will be considered as the standard one. The Pleo's touch sensors and RFID capacity will be exploited. The camera's output can be also processed, but it will take a lot of computing resources, so it will be mainly considered for the second case, when a PC is available in the background. In the second case, all the PC's potentiality is available, so standard computer vision paradigms will be considered, considering that the Pleo robot is the final interface with the user. As a third outcome, soft computing algorithms should be modularized in an easy form such that it can be implemented like simple building blocks in the programming environment before mentioned.

It has been named like Target behaviours those that would be defined Robot behaviours in the usual robotic literature of robot learning. However, and related with the next technical area, it should differentiated in this project between 'internal robot behaviours' (Target behaviours) and 'behaviours' (Robotic behaviours from the human robot interaction literature). Target behaviours are those computing algorithms programmed in the robot in order to obtain a certain goal (avoid an obstacle', touch a chair'). When interacting with children, goals are interaction goals, so they are defined like 'child smile', 'child stay touching the robot'. From the point of view of the effective interaction, robot behaviours are those that children observe in the robot, according to his/her impression. For instance, target behaviour for the robot can be 'to speak softly', however it can be observed differently by the child, so the effective interaction goal has not been met and no behaviour is recognized. In the Figure 1, a scheme about how robot learning is implemented is depicted: basic hardware actions are managed for a middle-ware layer in the form of simple blocks that are managed by soft computing blocks to learn and adapt to the user in order to obtain certain target behaviours. These behaviours will be understood by the child through the interaction as certain behaviour of the robot.

Finally, soft-computing techniques for data mining will be employed in order to correlate data temporal series recorded by the robot (sensors and actuators) with clinical variables and psychological ones. In this form, a 'training set' will be built when robots are interacting with children in short-term periods and extracted knowledge will be extrapolated for longer interaction periods. In this form, as the most advanced contribution in this work, it is hypothesized that a evaluation scale could be designed. Hence, observing evolved behaviours in robots it can be supposed how anxiety and pain was affecting children.

2.3 Children-robot Companionship

Robot programming modules will be designed with the aim to obtain positive interaction with hospitalized children. Effectiveness of the interaction will be checked through short, middle, and long-term interaction programs designed by both, hospital professionals and experts in interaction. A first out-

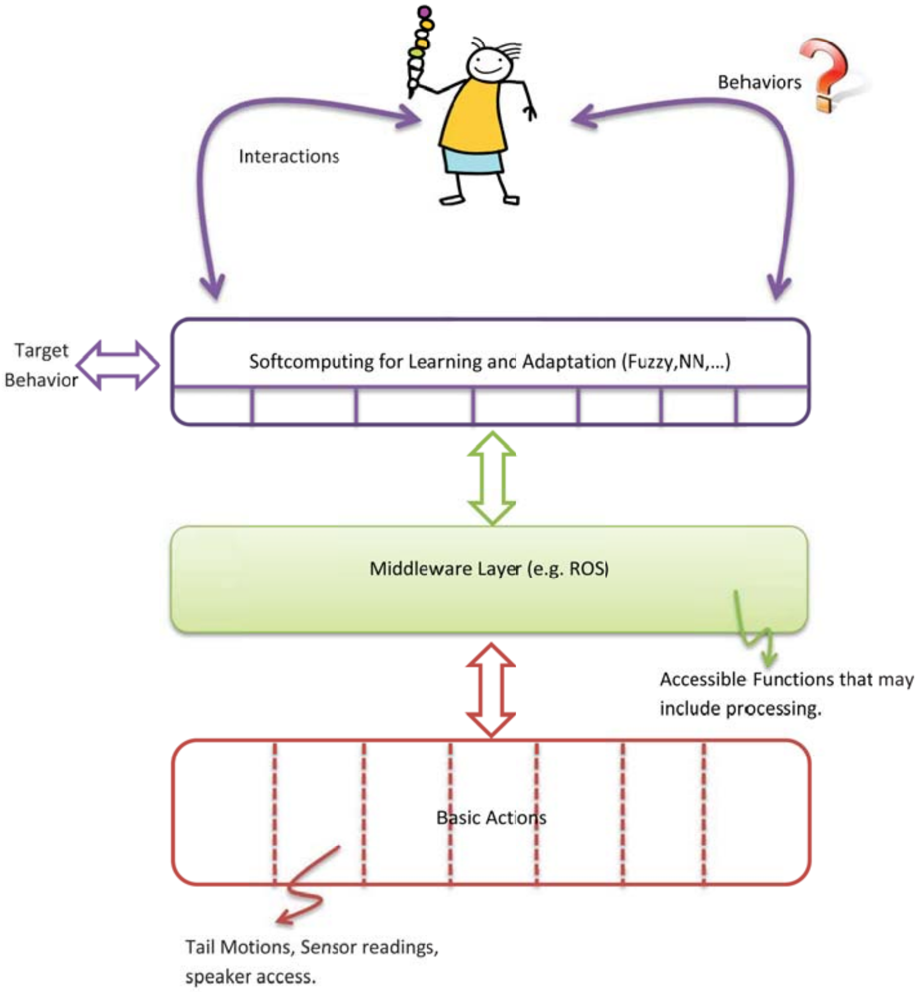

Figure 1: Implementing robot learning for 'internal robot behaviours' (Target behaviours) and 'behaviours' (Robotic behaviours from the human robot interaction literature).

come expected from this block is an assessment of interactive behaviour. Existing metrics and techniques for HRI measurement and analysis would be reviewed. As a second outcome, a study about child-robot relationship emergence and dynamics will be carried out and evidence based guidelines will be obtained for human robot interaction design. Finally, the impact of companionship on children psychological states will be measured.

2.4 Children Well-being and Health

The last part, but the main goal in this proposal is about how pet robot companions can help to improve well-being and health of children with some serious health problem supervised at Hospital Sant Joan de Déu (HSJD), both as in or out patients. The vast experience of the multidisciplinary group in HSJD with programs for improving quality of life ensures a high quality research for the experimentation. One of the problems that HSJD faces when implementing quality of life programs is how to measure the efficiency of the program. There are not reliable methods to assess children's appraisal on hospitalization and health from a multidimensional perspective and regardless of their specific diseases. This project will serve as well to develop a battery of assessment instruments to determine the impact of program on their quality of life, which could be applied to other programs of quality of life.

3 Background and State-of-the-art

Background and State-of-the-art will be introduced starting from the point of view of the target users, children suffering from some health problem, to the technological solutions implemented in the form of a pet robot companion, through the design of the interaction for the effective human social robot interaction.

Technological advances in healthcare are not always accompanied by attention to children's overall well-being and concern for their anxieties, fears, and emotional suffering. Very often it is difficult to eliminate negative childhood psychosocial responses to healthcare experiences. Children, youth and families continue to be traumatized by healthcare experiences and practices that are unresponsive to the developmental, informational, emotional and family support needs of children and youth. Any initiative to enhance the positive experience of acute and chronic disease (with or without hospitalization) and to increase the perception of health indicators and quality of life is a reason that justifies the proposed study.

The effectiveness of play (different types) in contributing to the decrease in anxiety and fear of the child with need of medical-health care is a topic extensively studied and demonstrated [Ishizaki *et al.*, 2012; McQueen *et al.*, 2012]. The activities of the child's interaction with the robot could be understood as a form of play.

Coping with the changes made by the individual, both physical and psychological, caused by the diagnosis of a chronic disease can lead to a number of behaviors which respond to emotional reactions such as anxiety (when the risk factor is important), anger (when considering an unjustified attack), guilt (if they try to explain the disease based on some cause) or depression (if interpreted as a loss or damage).

The usual experiences of pain, organ damage and intrusive treatments, particularly in chronic patients, cause changes in the representation of the body in ill children and adolescents [Cohen *et al.*, 2001]. These bodily changes and mental suffering can lead to feelings of inferiority when they confront with other people (the child feels different because of their illness), sadness and shame, with consequences for their self-concept and self-esteem.

The child's adjustment to chronic illness is determined by the interaction between risk and protective factors. Three factors are essential in the risk factors of disease variables (severity, visibility and associated medical problems), level of independent functioning of the child, and psychosocial stressors that are related to the disease. Among protective factors there are the intrapersonal variables (temperament, ability to solve problems, etc..), social ecology (family environment, social support, community resources) and skills in processing stress (cognitive appraisal and coping strategies)

Social engaging robots permit to establish satisfactory long-term relationship with people have already been proposed as supplementary tool for rehabilitation, autism therapy, treatment adherence and compliance, and even provide entertainment, enjoyment and comfort [Okamura *et al.*, 2010]. For paediatrics purposes, [Kozima *et al.*, 2005] found that interaction with pet-robots has shown beneficial effects for learning and communication for children with motor disabilities and autism, respectively. Furthermore, FP6 project IROMEC is developing a toy robot for the therapy and education of children with special needs [Ferrari *et al.*, 2009]. Pet-like robots have been introduced to reproduce the social-emotional benefits associated with the interaction and the emotional bond between children and companion animals such as entertainment, relief, support and enjoyment.

Social robotic interaction can include the activity of playing games with the goal to recreate situations of distraction and entertainment. Through playing games, children are actively involved with the activity at hand, and some even become completely immersed in the game world. To assess the effects of the experience with the robot on the user, it is necessary to determinate categories that contemplate issues as emotional connection, coolness/entertainment, humour and level of immersion. Other authors [Steinfeld *et al.*, 2006] propose different categories to evaluate the grade of social interaction with the robots: Interaction characteristics, Persuasiveness, Trust, Engagement and Compliance.

Robots, due to their embodied nature, encourage social interaction more than other artificial agents, like digital avatars, and create a unique interaction experience [Young *et al.*, 2011]. For long-term interaction, work in [Kanda *et al.*, 2007] proposes three design principles for enhancing interaction: say children's name, pseudo development, and confiding personal matters. Always for long-term interaction, [Kidd and Breazeal, 2008] consider that two key features exist to elicit enduring involvement between robots and users: the ability to look at the user (or appear to do so) for drawing a person into the interaction, and the system adaptability to the interaction flow (specificity and timeliness) and to the relationship dynamics.

4 Work Methodology

A methodology that involves overcoming five stages is suggested for the research project:

1. Multidisciplinary analysis of the multifaceted problems of engagement and socialization when dealing with children having a health problem in 3 different situations: Emergency department, Hospitalization, and Chronic outpatient control (chronic patients at home).
2. Requirement analysis, development of robot software/hardware modules and initial interaction settings to be tested on an initial short-term target group in each group of patients.
3. Analysis and feedback from research in the initial experimentation. Evaluation of the interaction and impact on children' psychological state in each group of patients.
4. Short, middle and long-term experimentation with target groups of ill children. This phase will overlap software developments in the previous phase.
5. Analysis from research in the experimentation. Evaluation of the interaction and impact on children' quality of life and clinical outcomes.

The proposal has been structured in a set of tasks developing each of the goals previously outlined. To maximize the effectiveness of the interaction, a methodology of user-centred design and usability engineering will be applied. For this end, it has been integrated throughout the entire cycle of project development (especially in stages 3 and 4) feedback from users and stakeholders (direct users, caregivers, prescribers, and family). This iteration through the initial design, evaluation and redesign cycle will allow to select between alternatives based on the quality of the observed user experience in such a way that ensures that the users' needs are sufficiently addressed by the pet robot behaviours.

With reference to the statistical analyses, summary of study's data will be presented, showing different measures of central trend (mean, median and mode) and dispersion (standard deviation, quartiles, rank). The homogeneity of the main variables in the study between groups at the baseline moment will be tested with the Student T test in case of variables normally distributed. In other case, non-parametric tests will be chosen. Mixed models of random and fixed effects will be used to perform analyses of repeated measures collected along the different assessment moments in the study period. These models will include interactions terms and confounding variables in case of needed. A data base designed for this study will store the collected data.

The sample size was fixed at 30 subjects per group. Given the low number of similar studies, the sample size has a power of 80% and a confidence of 95% to detect the mean differences pointed out as a relevant variation by the research team between treatment and control group for the main scales assessed in this study. This sample size calculation includes a 10% of losses for possible lack of follow-up.

4.1 Multidisciplinary Analysis

Firstly, conditions to be met by the pet robot to integrate it in the hospitalization environment should be identified. Hence, it is necessary to set-up how to conduct relational settings between children and robots, whether exist or not the resources needed to carry it out, support of the social environment, the compatibility with their abilities, preferences and motivations. In the Figure 2, a scheme is presented about how robot-children interaction will be studied from three perspectives: clinical variables, psychological variables (by direct observation) and robotics temporal series. Two commonly recognized scales will be employed to relate clinical and psychological variables: anxiety scale, i.e. the Anxiety Visual Analogue Scale [Colwell *et al.*, 1996; Williams *et al.*, 2010] or the well-known STAI-C [Kri, 1996] (which discriminates state anxiety and trait anxiety in children), and the FLACC scale (Face, Legs, Activity, Cry, Consolability, from Merkel et al) scale [Merkel *et al.*, 1997; Bai *et al.*, 2010]. In this form, the first objective, i.e. using robots to help to reduce pain and anxiety in children, can be measured. For the second, and more ambitious, research objective, soft-computing techniques will be employed to extract knowledge from correlated variables (clinical, psychological and temporal series). In this form we hypothesize that conclusions about children's pain and anxiety experiences can be extracted from observing how the robot behaviour has been modified when interacting with children. All these measurements will be done in the different target groups we defined: children being seen at the Emergency Department, being looked after during their hospitalization, or being at home living with their chronic condition.

In summary, three scenarios will be considered for our research, ranging from short-term, middle-term and long-term

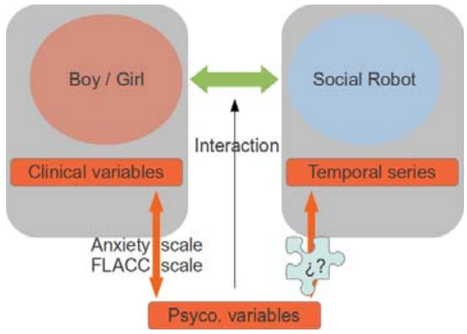

Figure 2: Robot-children interaction will be studied from three perspectives: clinical variables, psychological variables (by direct observation) and robotics temporal series.

interaction. Hence, nine possibilities are available for study, starting from (1) using robots with children in short-term relationships (like ER), where novelty effect will work, until (9) extracting conclusions about children's anxiety and pain experiences by observing how robot behaviour has evolved in a long-term scenario, interacting at home.

In particular, research will initially focus in middle-term and long-term interaction and evaluating anxiety scales. Depending on achievements, we will stay there, we will move towards scenario (9), or, in the worst case, we will reduce our expectations to more simple scenarios. Considered scenarios include medical procedures like sutures, venipunctures, injections or wound cleasing.

4.2 Analysis of Basics Requirements

To the development of useful robot software modules, robot behaviours and initial interaction settings to be experimented on an initial target group, we rely on models of psychosocial acceptance of technology (Technological Acceptance Models) [Davis, 1989] and specifically in the knowledge available about the acceptability of robotics. These models argue that the motivation to take up and use well (willingness to make continued efforts to do so) any new device, is determined primarily by the relationship between the value received by the user and the perceived difficulty of using it. This model is dynamic – both dimensions are influenced by the environment and the experience – and it includes the social environment of the person.

Hence, the purpose is to apply identified user profiles and contexts of use to design and develop interaction settings. These settings will be experimented on both, an initial group of non-hospitalized children, who will serve as initial training and control group, and basic short-term interactions with children suffering a limited stroke. In this form, novelty will help to design effective interaction settings to be extrapolated in longer interactions.

4.3 Initial Feedback

Past experimentation will provide a lot of information that will be analysed and extrapolated to the middle and long-term scenarios. This experience will help to define the most successful software modules, interaction settings and more useful tests for users who experienced a closer interaction with the platform. In this moment, several 'contingency plans' can be selected among the nine possibilities aforementioned: it could happen that experimentation with the pet robots would not been satisfactory and useful to initial users, so it can be needed to rethink the testing of the previous phase, and in any case, the feedback should allow make an adjustment or fine tuning of the system for the users. Conversely, children's satisfaction and data extracted from robot's sensors and actuators could be rich enough to continue towards a data mining study about variables correlation.

4.4 Experimentation and their Analysis

Long-term experimentation in the target scenario will be developed. The objectives of engagement and socialization will be validated and the results will be analysed from all developed points of view, especially the achievement of the socialization, useful to reduce the children's anxiety, stress, pain and/or fear.

5 Conclusions and Further Research

Children being diagnosed with a certain illness will experience unfamiliar and stressful procedures while they are in the hospital. In order to minimize the negative psychological impact of hospitalisation and treatment procedures, different programmes have been designed and implemented. In this sense, the initial hypothesis for the introduced proposal is that using pet robots endowed with socially situated behaviour able to develop the role of companion will help to cope with these stressful situations along all the hospitalization period and/or outpatient treatment. In order to obtain socialization for the pet robots, appropriated software modules based on soft computing techniques will be developed according to a quality of life program. Moreover, children's anxiety and pain levels could be measured by observing how robots interacting with children have modified its behaviour.

The proposed research project represents a qualitative leap in the evaluation of social robotic systems to promote health and quality of life. Specifically, the following scientific and technical contributions are expected:

- Creating human social robot interaction based on a pet robot as the main agent with limited processing elements, computation and support interfaces.
- Development of a measurement tool to assess the best experiences of interaction based on the quality and usefulness of the interaction (engagement and socialization) generated in a specific scenario of social interaction.
- Making in effective form modular software/hardware for robotic systems that are capable of providing experiences that promote the quality of life in hospitalized children.

In addition, results expected over the long term in further research should be added:

- Development of robotic interaction, software and hardware modules.
- Easy extrapolation of the developed environments to companies (assisted houses), public facilities (areas of monitoring and external care) and administration (daycare centres).
- Development of a novel methodology for the analysis of requirements, development and deployment of Environmental Robotics (interaction user - environment robot).

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